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EMIT
EARTH SURFACE MINERAL DUST SOURCE INVESTIGATION

# EMIT: A New Space Imaging Spectrometer Mission to Advance Modeling of the Earth System

# Earth Surface Mineral Dust Source Investigation (EMIT)

(Photo: Todd Morris/Flickr)

(Photo: Ianz/Flickr)

Robert O. Green, Natalie Mahowald and the EMIT Team

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

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# Co Authors and EMIT Science Team

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| Vincent Realmuto | JPL California Institute of Technology |
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| Eyal Ben Dor | University of Tel Aviv |

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# Mineral Dust Impacts Across the Earth System

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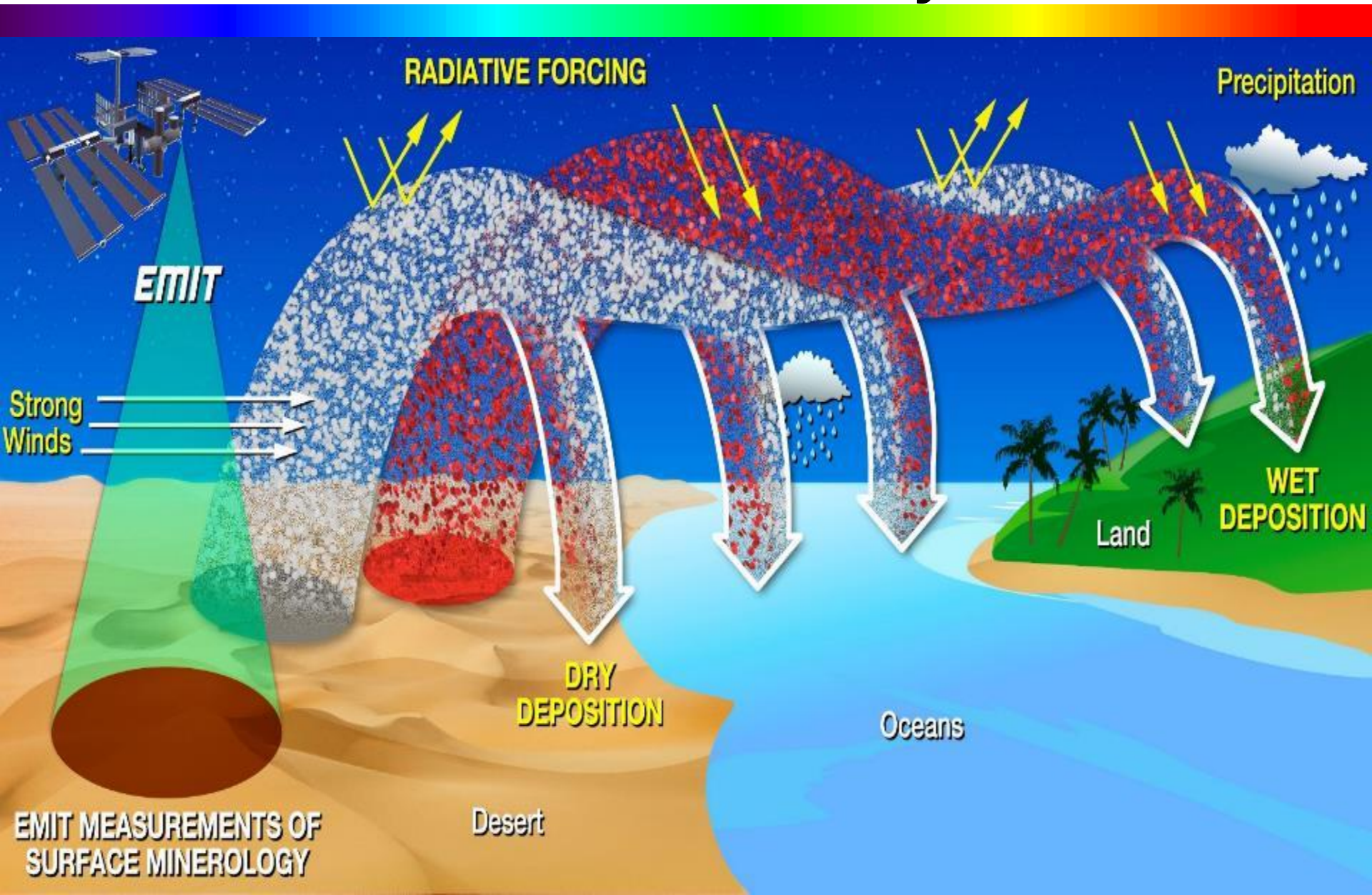

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# Models are Used to Assess the Current and Future Impacts of Mineral Dust

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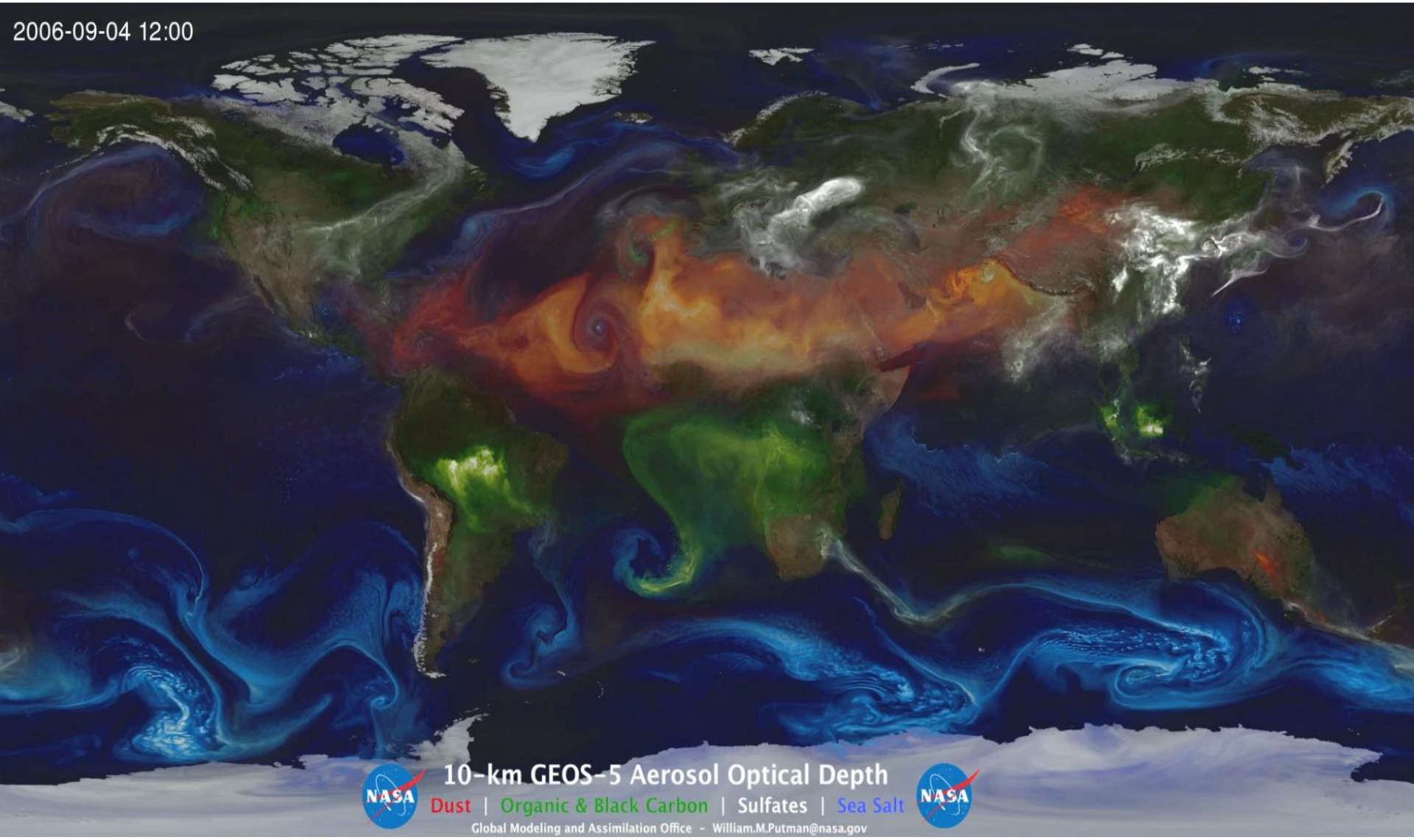
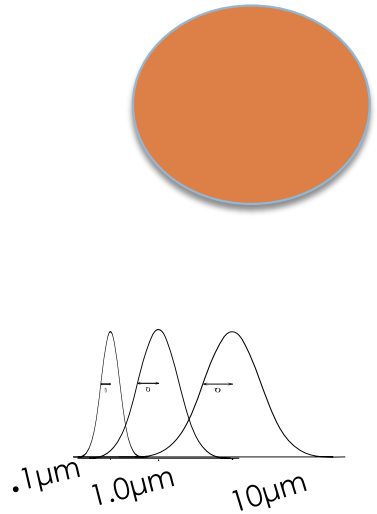


# Dust in Earth System Models

Traditionally:
Model an 'average'
Mineral aerosol




But mineral aerosols are from different minerals depending on surface properties


Illite


hematite


kaolinite


quartz

feldspar

montmorillonite

In 3 aerosol size modes
(Zender et al., 2003; Mahowald et al., 2006;Liu et al., 2011)

And each mineral has different properties and interactions with Earth System

Iron oxides:
Absorb SW, iron for ocean biogeochemistry

Kaolinite:
Reflects SW, high pH

Feldspar: ice nuclei source

Clays, large particles: LW interactions

Scanza et al., 2015; 2018

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# Building dust into models

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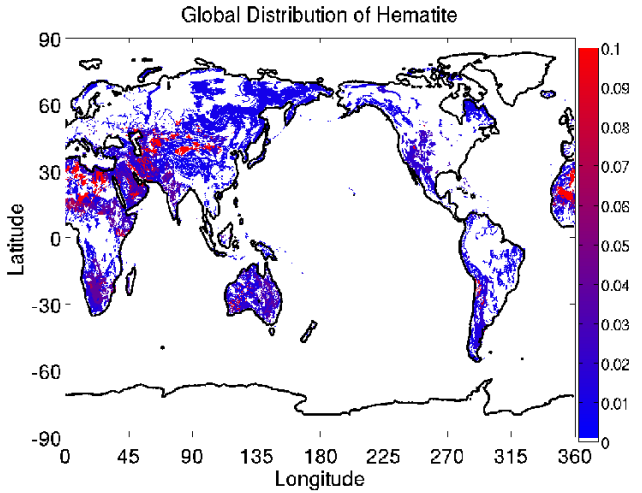
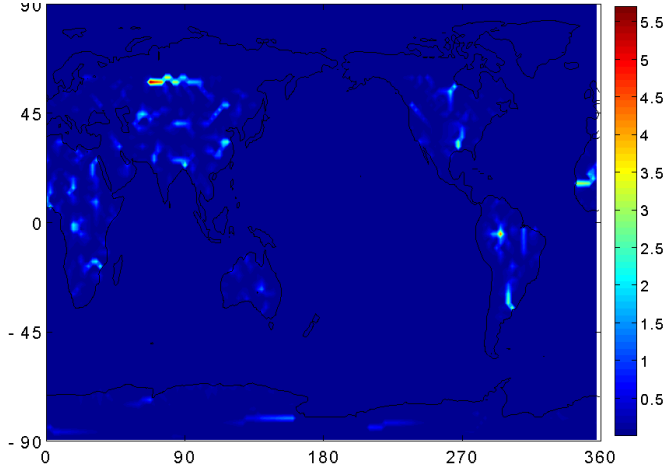
Using **FAO soil datasets** and "average" minerals in each soil type




X

Dust emissions

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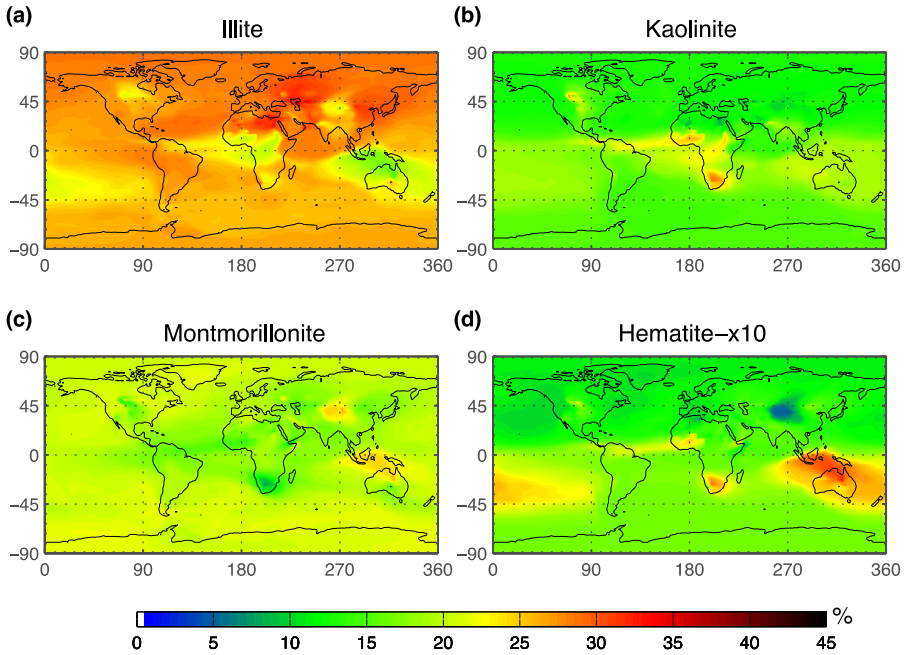


In this implementation, including mineralogy details, the sign of radiative forcing switched from slightly cooling to slightly warming. An important difference.

Scanza et al., 2015

# Example: Current Mineral Dust Source Information

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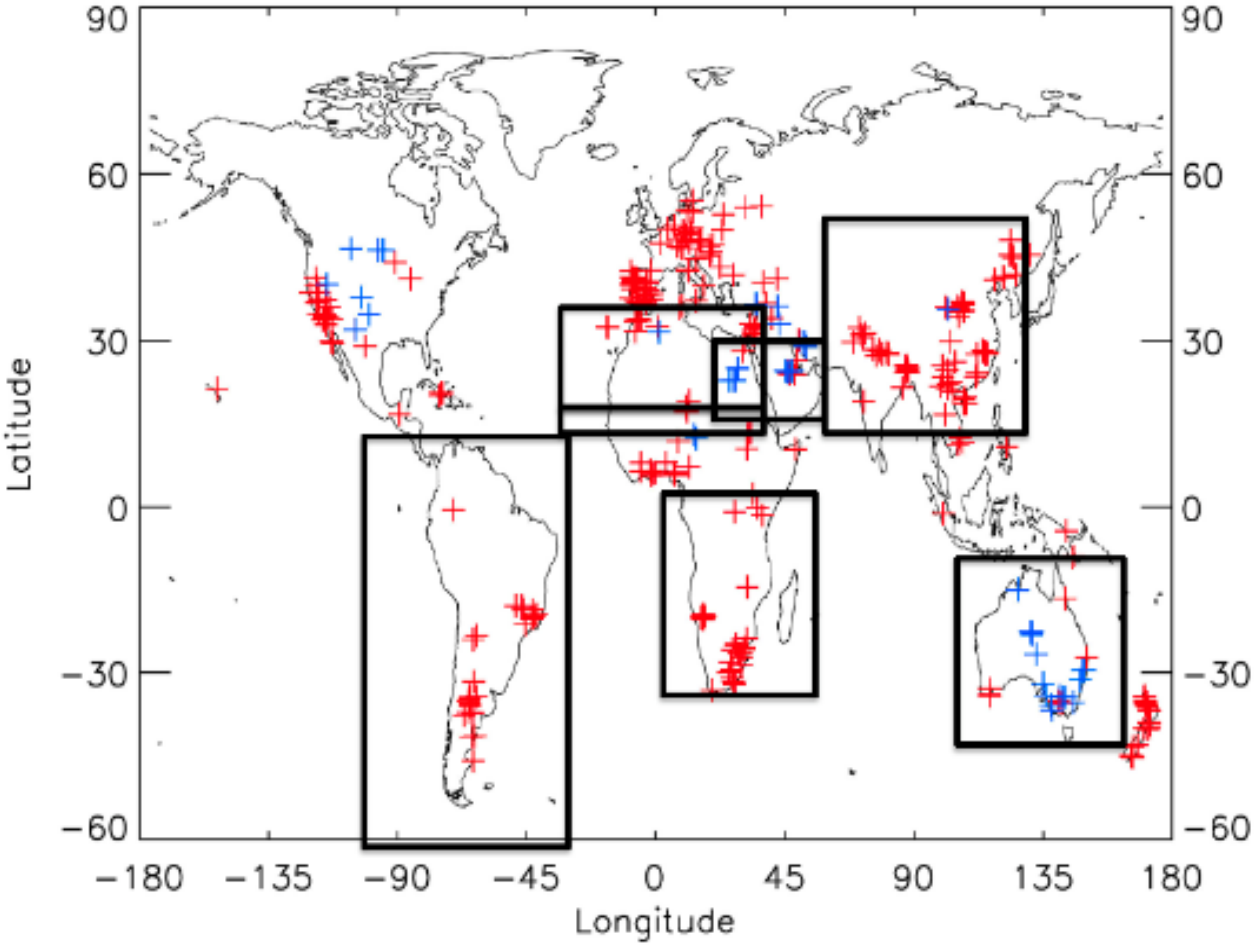
Current Soil Sample Locations




Journet et al., 2014

Concern: Using FAO soil data sets and "Average" soil properties from ≤5000 soils samples (mostly not in deserts) doesn't fully capture actual distribution and diversity.

New observations of arid land regions can help.

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# Imaging Spectroscopy Offers an Approach to Measure the Surface

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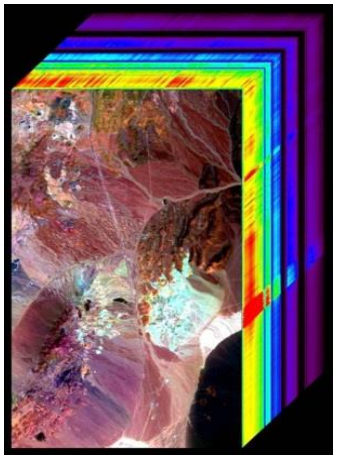
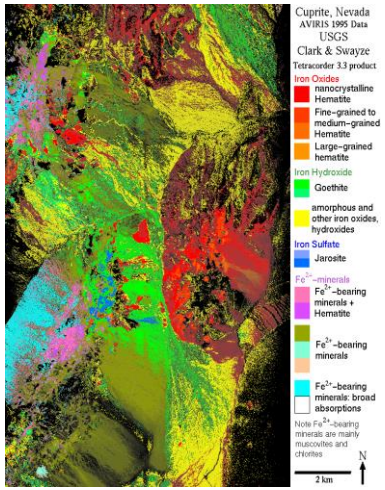
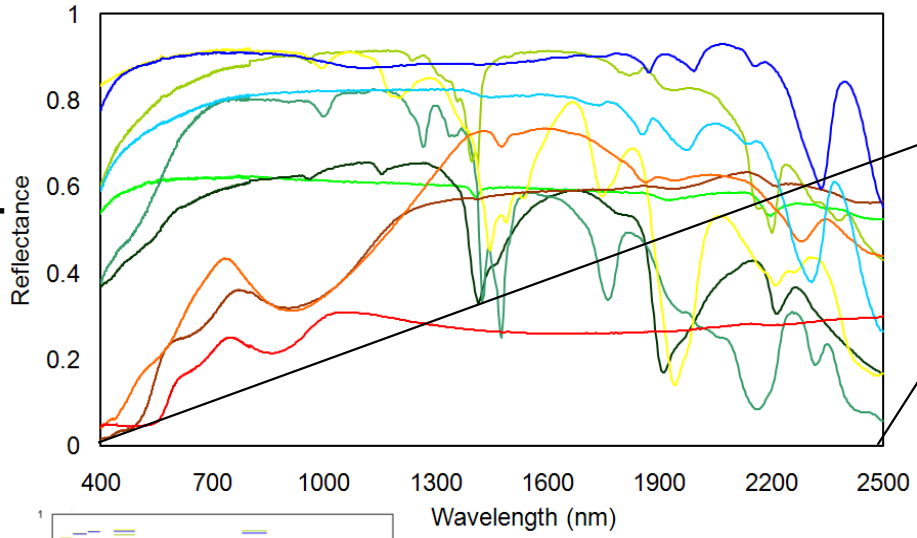
Calibrated Image Cube

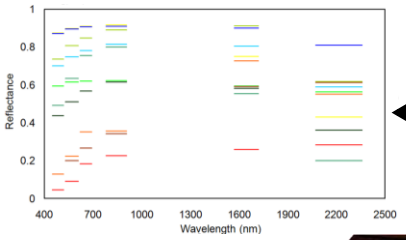


Material Map




1000s of Parallel Spectrometers



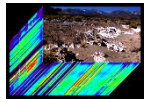




Multispectral

Space

Airborne

Ground

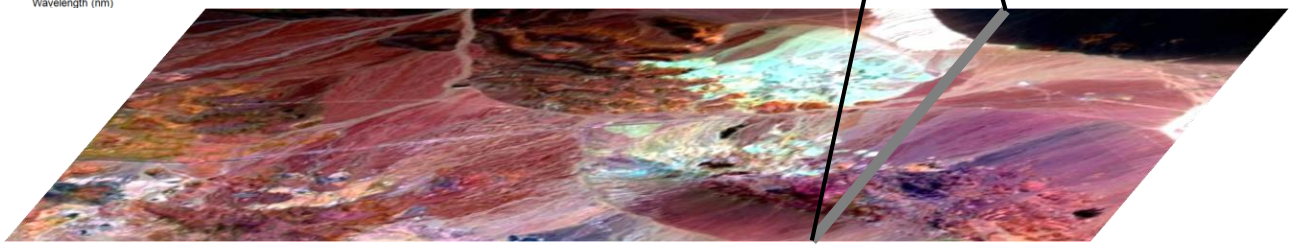


Detector Array

Spectrometer

Slit

Telescope



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# Moon Mineralogy Mapper (M3): Hydroxyl/Water Discovery

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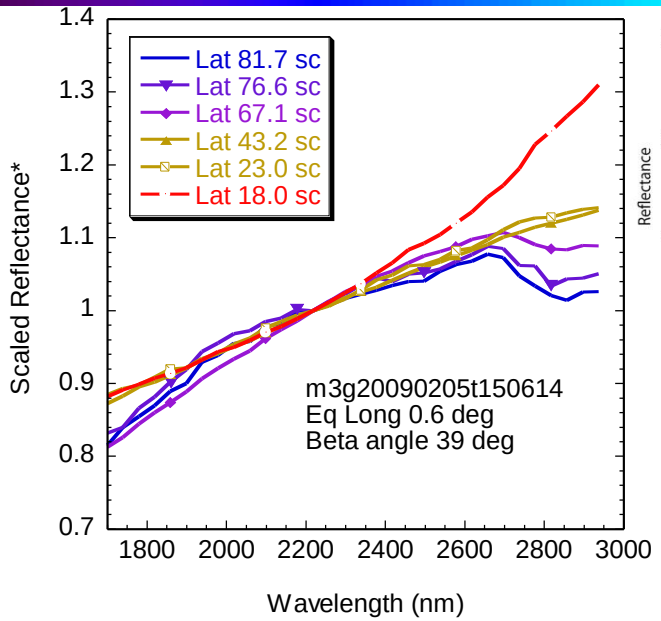
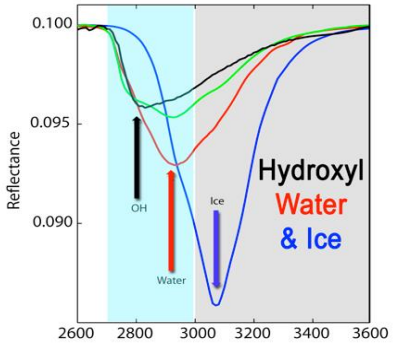
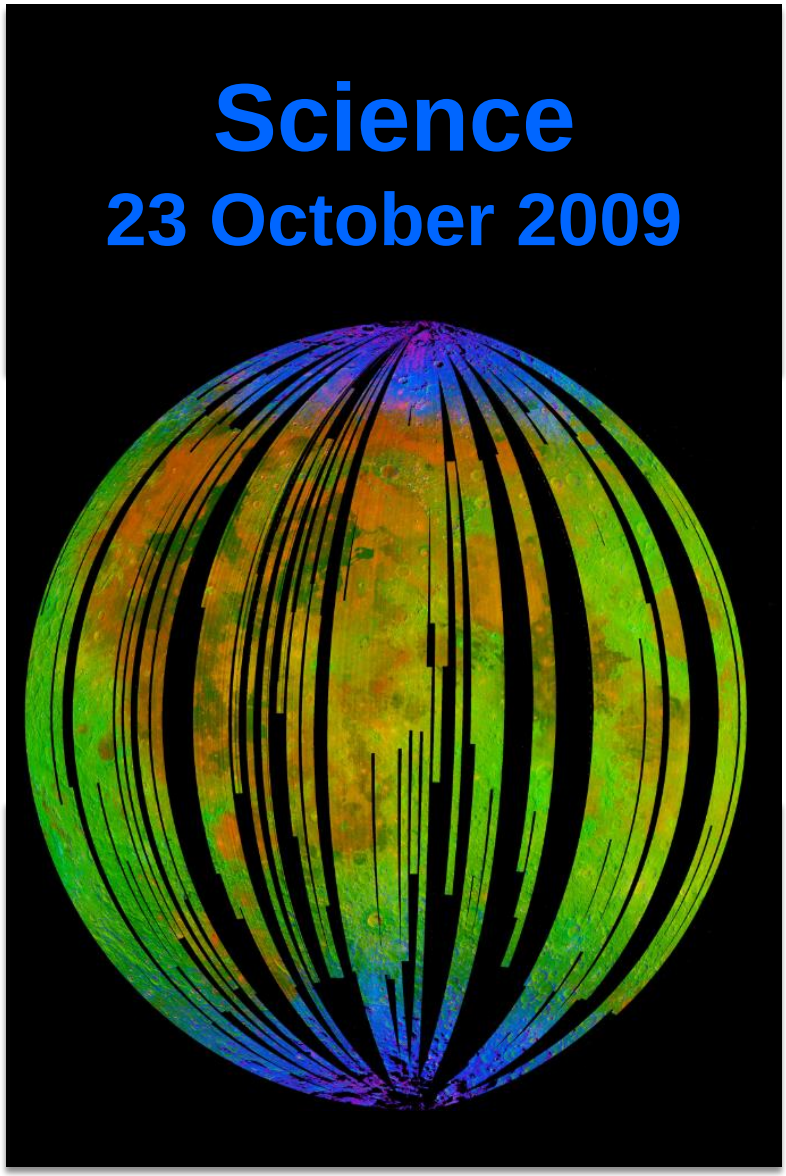
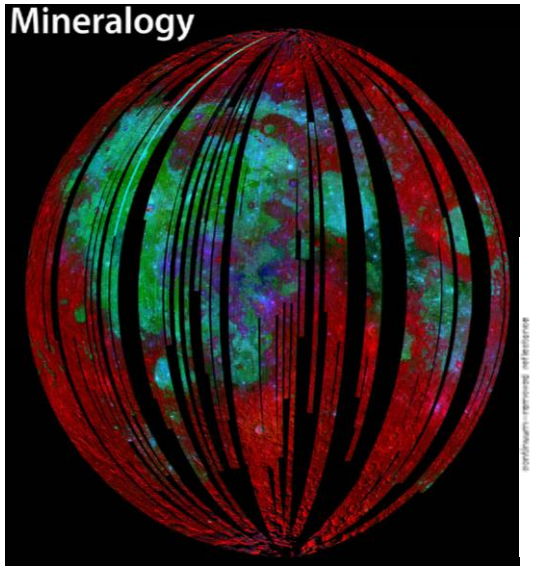


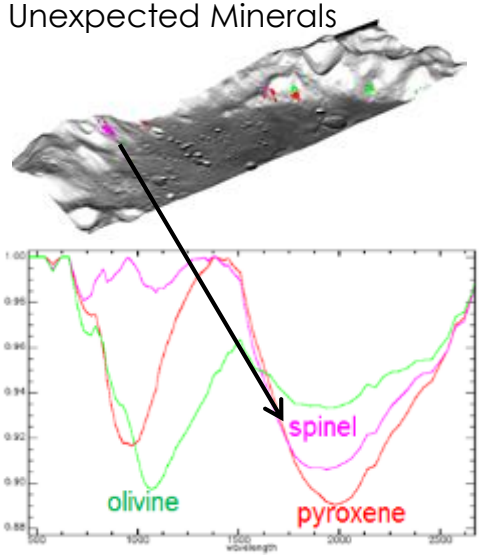




## Science
## 23 October 2009






Unexpected Minerals



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# FAO Soil Map Compared to Airborne VSWIR Imaging Spectroscopy

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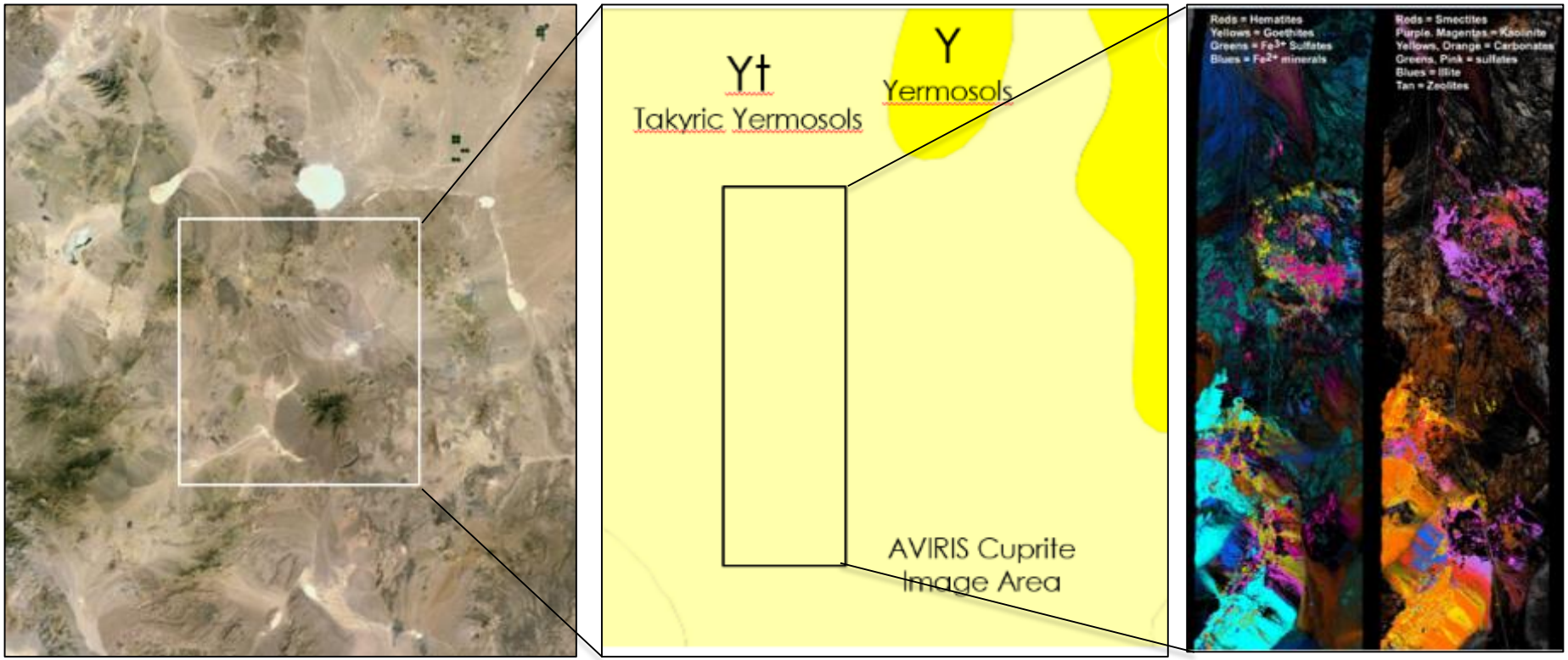
Cuprite, Nevada Region

Soil Map

VSWIR Imaging Spectroscopy




Imaging spectroscopy provides a tested method for direct comprehensive measurement of surface mineral composition for the Earth's mineral dust source regions.

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# Key Minerals of Interest have Distinct Spectral Signatures

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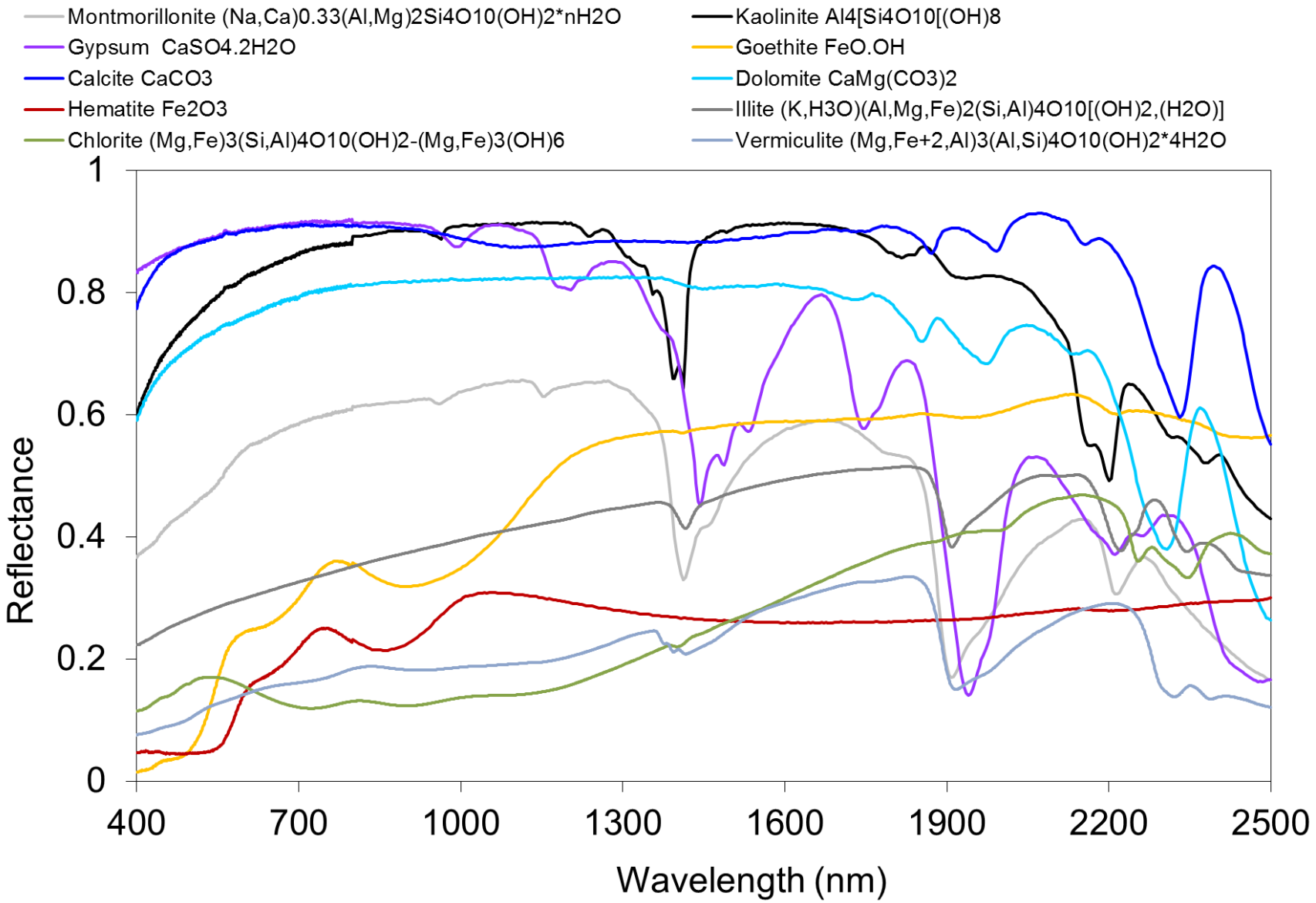
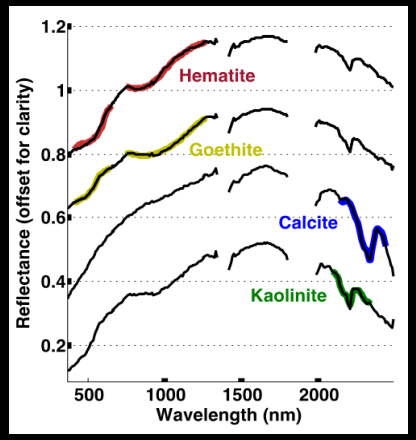
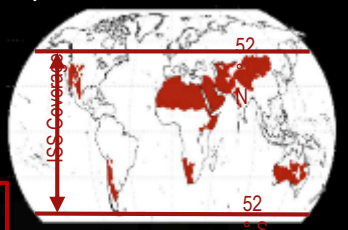
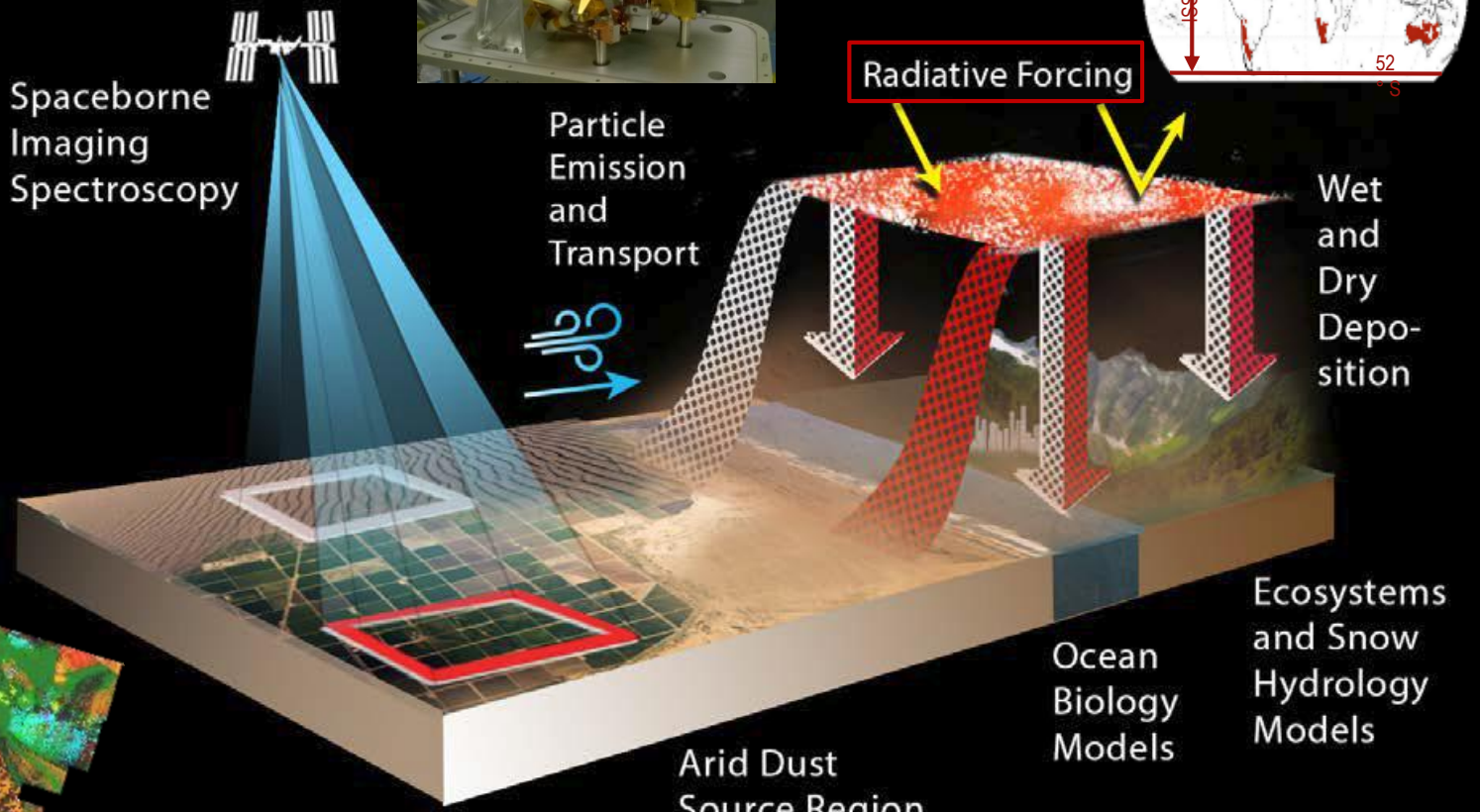


# EMIT Overview and Science Objectives

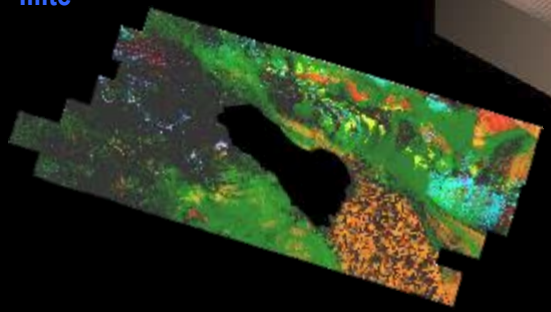
The source region composition for the Earth's mineral dust cycle is poorly known. Source knowledge is required to model the dust cycle and assess future scenarios. EMIT has two objectives.
1) Constrain the sign and magnitude of dust-related RF at regional and global scales. EMIT achieves this objective by acquiring, validating and delivering updates of surface mineralogy used to initialize ESMs.
2) Predict the increase or decrease of available dust sources under future climate scenarios. EMIT achieves this objective by initializing ESM forecast models with the mineralogy of soils exposed within at-risk lands bordering arid dust source regions.




Hematite
Goethtite
Carbonates
Clay Minerals
Illite



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# Mineral Dust and Radiative Forcing

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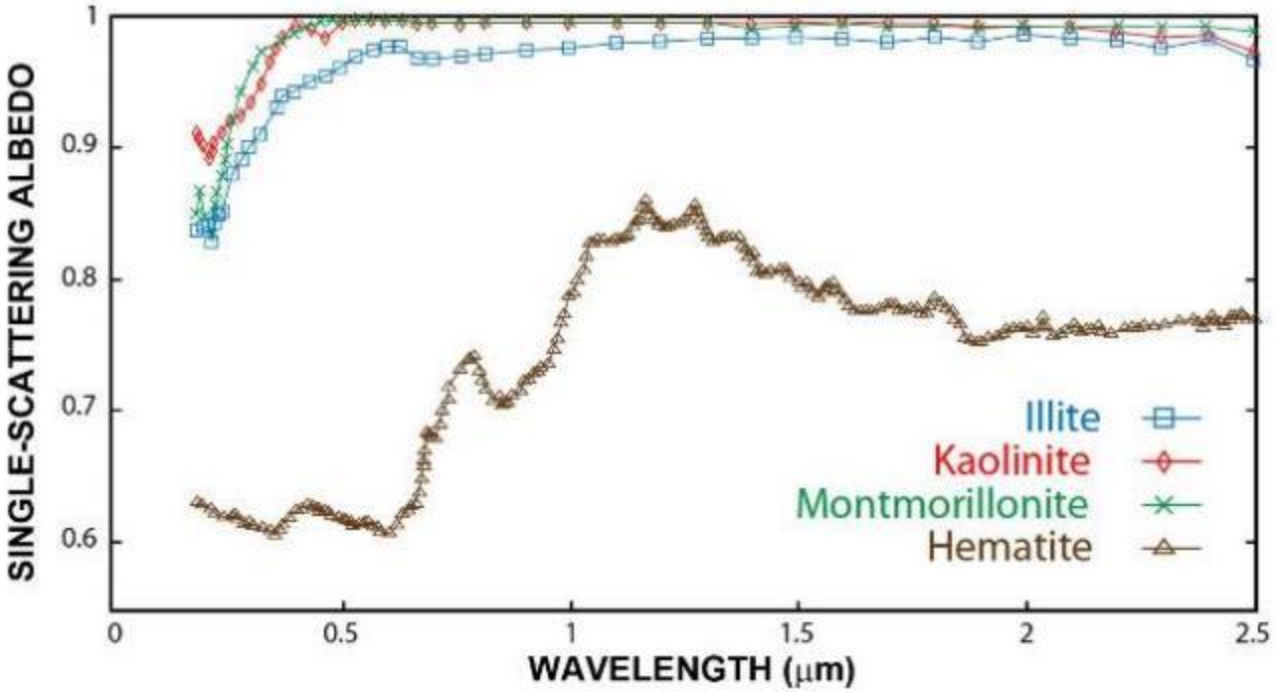
Radiative forcing: The change in the Earth's energy balance as a function of an imposed perturbation

The optical characteristics of mineral dust influence the amount of energy absorbed or radiated.

Mineral composition is a key control of single-scattering albedo (SSA), the ratio of scattering extinction to total extinction.

- Hematite is a strong absorber (SSA < 1.0) in the VSWIR, contributing to positive forcing (warming)

- Clay minerals (illite, kaolinite, and montmorillonite) are strong scatters (SSA ≈ 1.0), contributing to negative forcing (cooling)

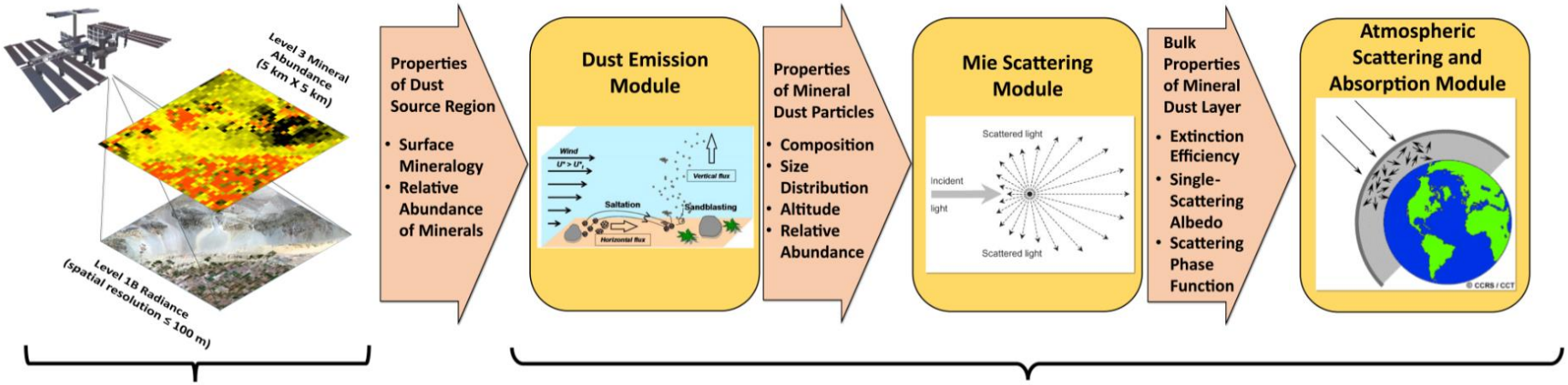



(modified from Sokolik and Toon, 1999)

# Model Status



- Earth System Models are ready to accept more detailed Earth surface mineral dust source information.
- Earth System Models are being improved each year.




(Photo: Todd Morris/Flickr)

(Photo: Ianz/Flickr)

# EMIT uses Imaging Spectroscopy to Map Dust Source Region Minerals

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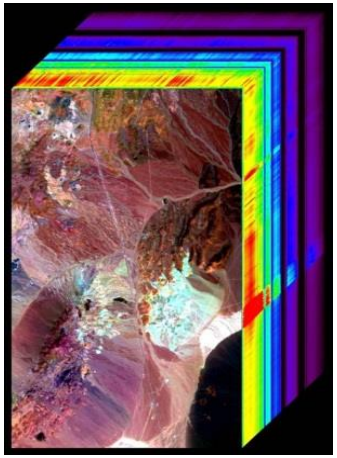
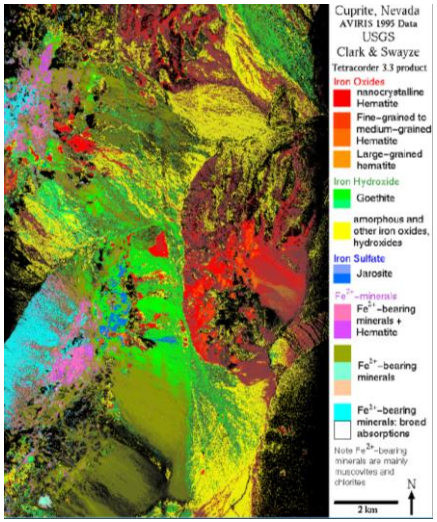
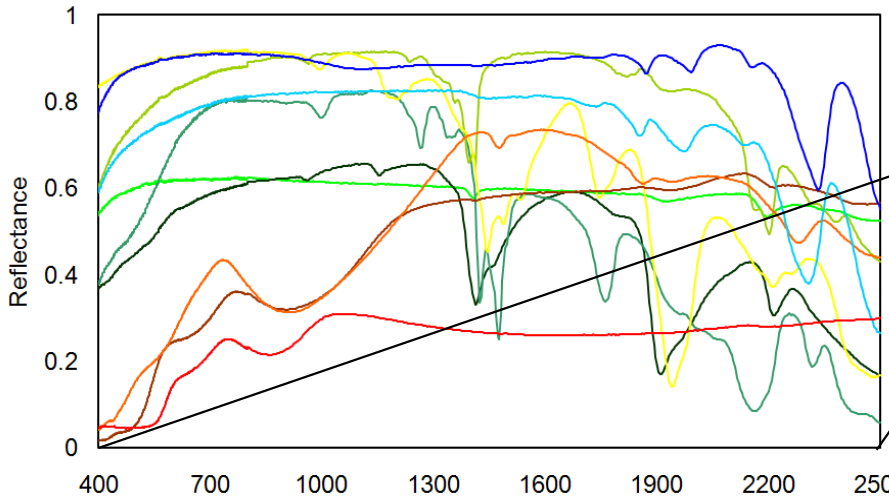
Image Cube



Mineral Map




1000s of Parallel Spectrometers




International Space Station

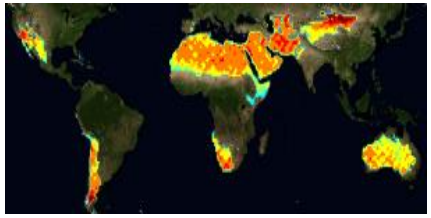
Detector Array

Spectrometer

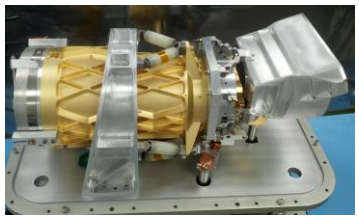
Slit

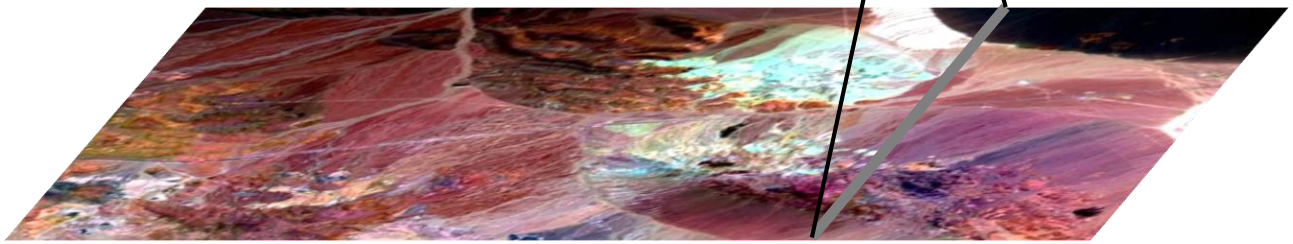
Telescope

Dust Source Regions



Prototype Spectrometer





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# Mineral Mapping Test in the Salton Sea, CA Dust Source Region

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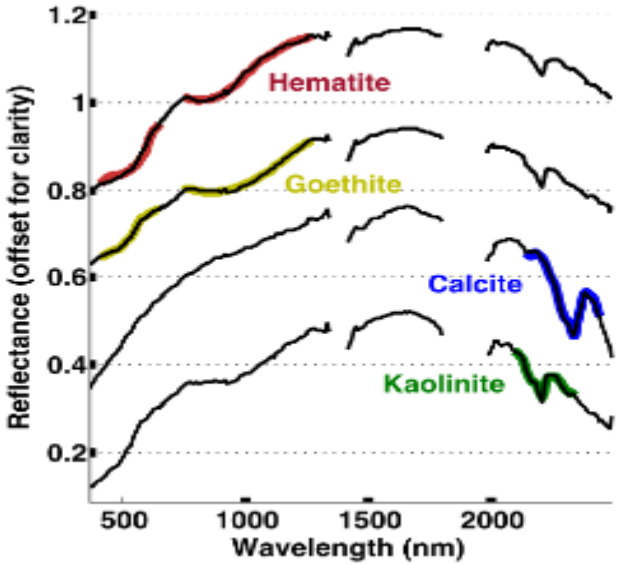
AVIRIS imaging spectroscopy measurements of the Salton Sea region in Southern California acquired as part of the 2014 NASA HyspIRI airborne campaign.




Hematite
Goethtite
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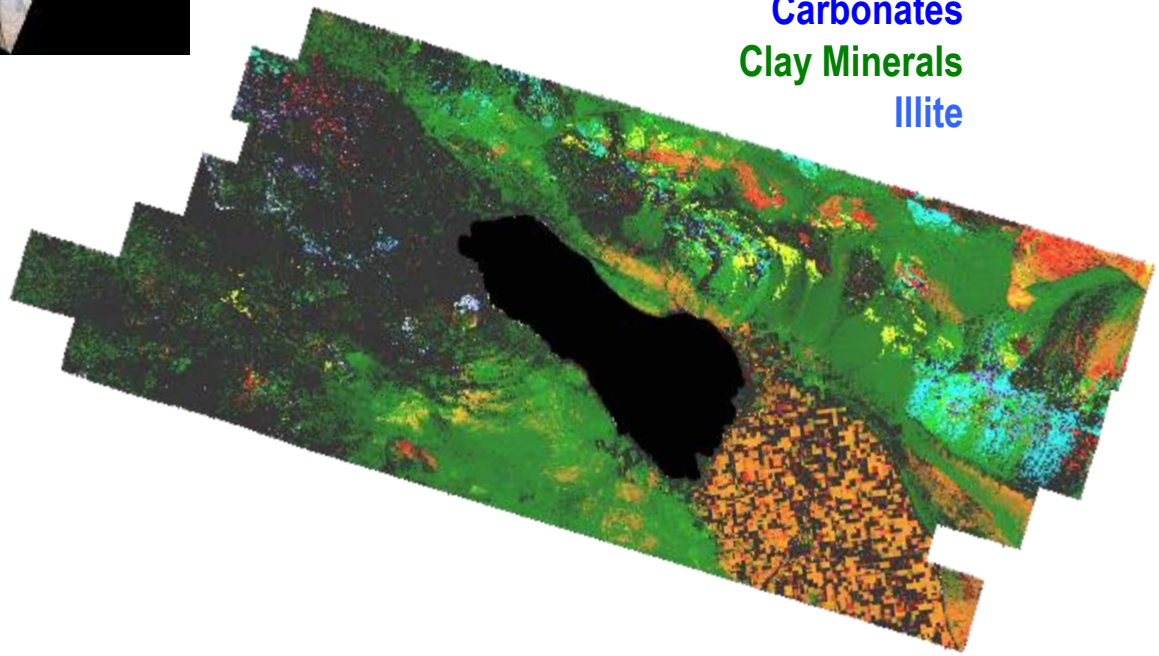
Illite



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# Validating the Mineral Spectroscopy at Salton Sea, CA

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# Existing FAO Mineralogy versus Imaging Spectroscopy

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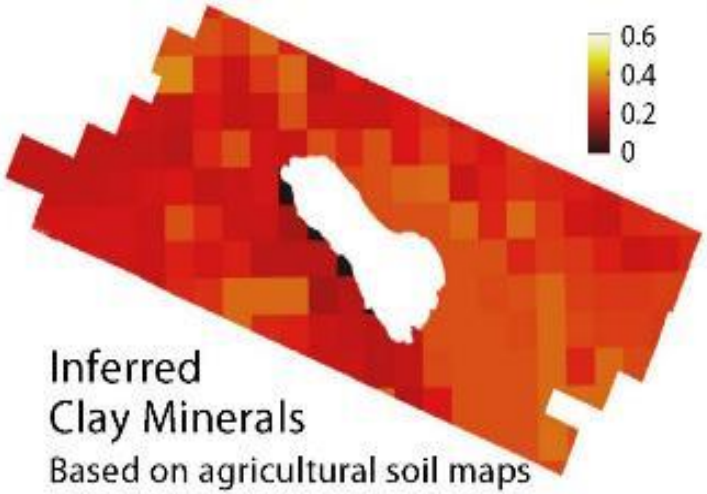
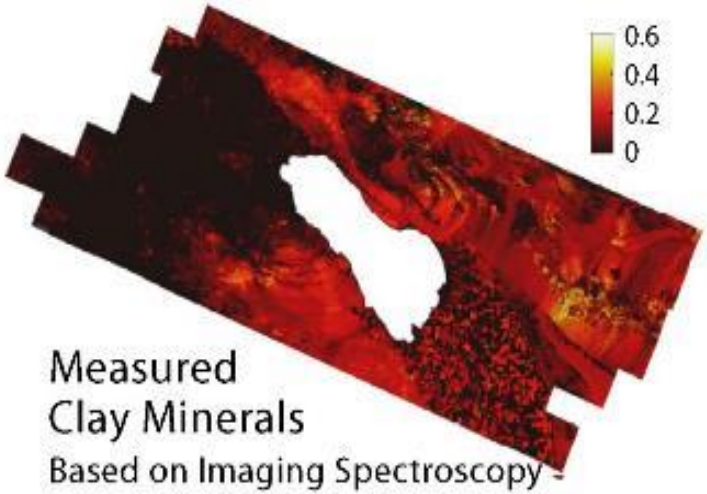
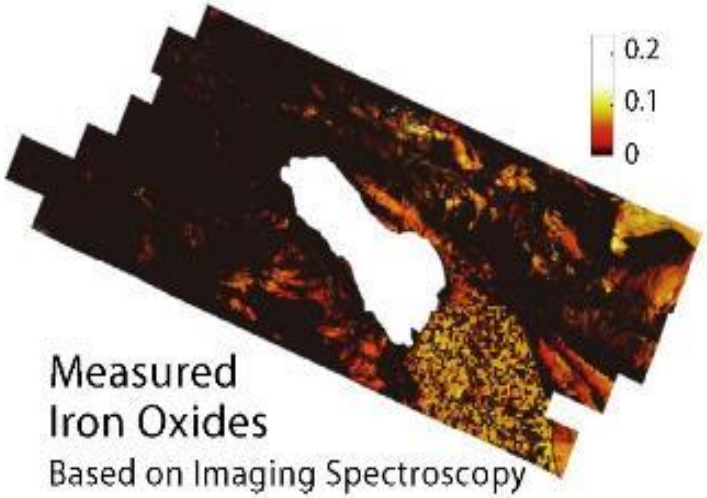
## FAO Based Minerals



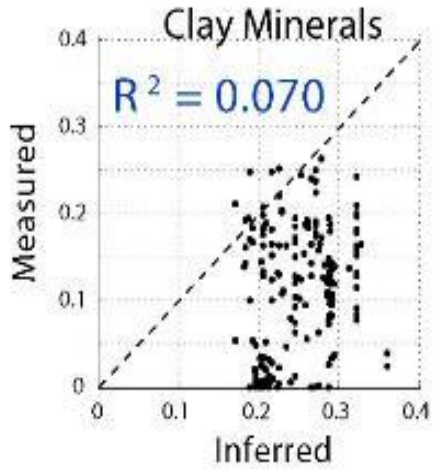


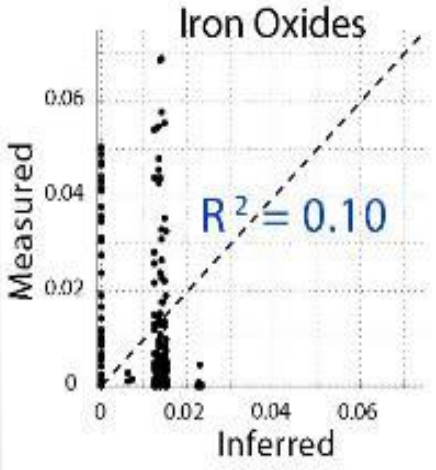
## VSWIR Spectroscopy




## Comparison



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# EMIT Target Areas are focused in the Arid Land Regions

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These occur under the orbit of the ISS.

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# ISS is Ideal for EMIT: ELC 1 Site 8, Nadir View

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# EMIT Instrument: F/1.8 VSWIR Dyson Imaging Spectrometer

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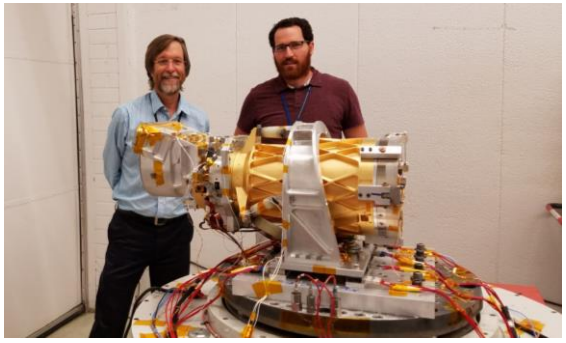
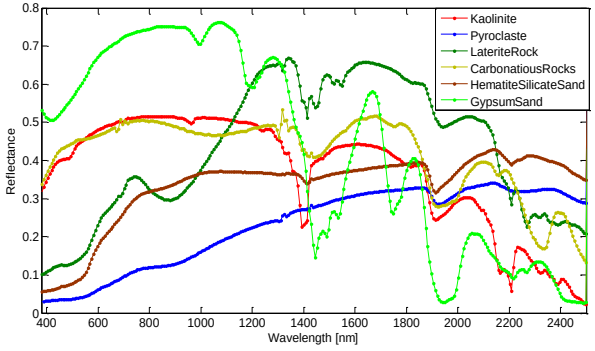
## Instrument Overview

EMIT is a Class C implementation of a mature F/1.8 VSWIR-Dyson Spectrometer that leverages NASA Research and Technology investments, including the ESTO IIP SWIS Dyson spectrometer.

Prototype Spectrometer



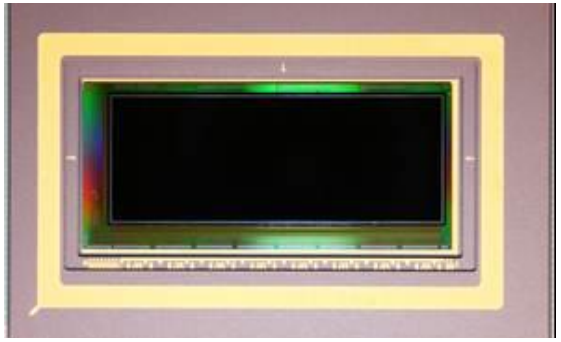
Test Spectra

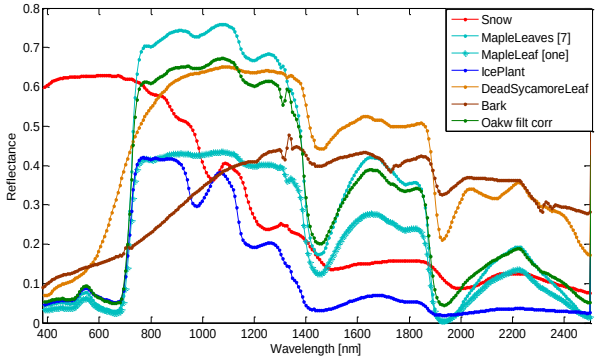



## EMIT measurement

Spectral: 380-2510 nm
Radiometric: ≥100 SNR in retrieval wavelengths, without saturation over bright land
Spatial: ~30 m sampling

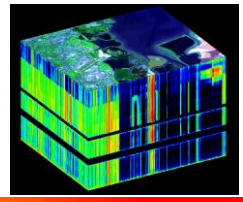
VSWIR Detector 1280 x 480






JPL
NASA National Aeronautics and Space Administration Goddard Institute for Space Studies New York, N.Y.
Cornell University
NOAA
PSI
UCLA
USGS science for a changing world
BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación

# The EMIT Instrument Draws from a Long History of Imaging Spectrometer Development

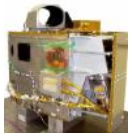


1982

1986

1989

1997



2000

1998

2005

2009

2008

24 Months

- First Imaging Spectrometer AIS proposed in 1979 first flights in 1982
- AVIRIS imaging spectrometer > 1000 refereed journal articles
- NIMS imaging spectrometer to Jupiter
- VIMS imaging spectrometer to Saturn
- MICAS Miniature Integrated Camera and Imaging Spectrometer to Comet
- Enabling partner in Hyperion-Earth, CRISM-Mars and ARTEMIS-Earth imaging spectrometers (gratings, designs, calibration, science)
- Proposed and Developed NASA Moon Mineralogy Mapper (M3)

EMIT-2018

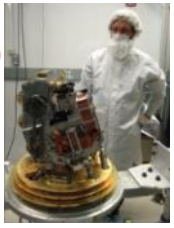
- > 7 Airborne/Rover-type Imaging Spectrometer operating at cryogenic temperature and in a vacuum (2005-2015)

MaRS 2005

24 Months

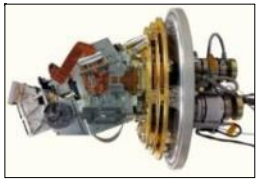
24 Months

CAO 2010

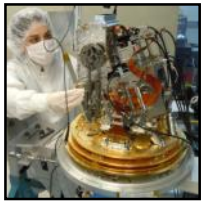


< 18 Months

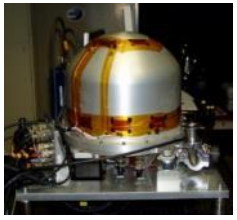
MSS 2011



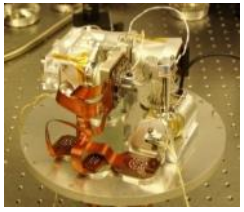
AVIRIS-NG 2012



PRISM 2012



UCIS 2013

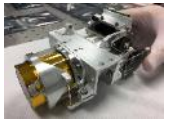


ESWIRS 2014

CWIS 2016

MISE 2017

SWIS 2017



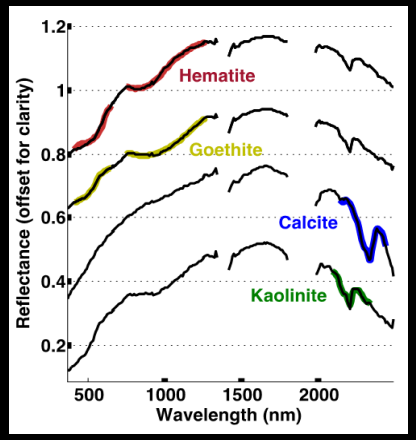
Jet Propulsion Laboratory
California Institute of Technology

# Summary and Conclusions

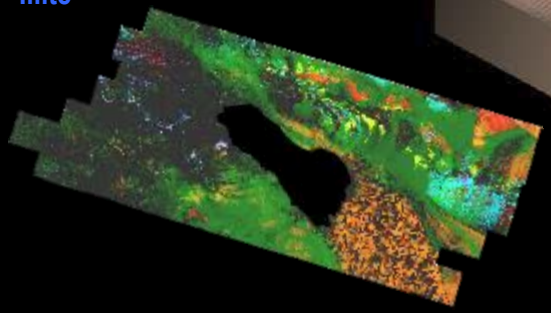
EMIT
Earth Surface Mineral Dust Source Investigation

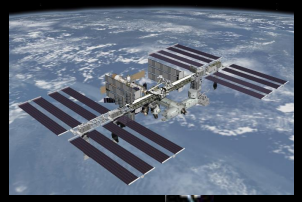
- The mineral dust cycle impacts many elements of the Earth system.
- To understand these impacts and predict how they may change in future climate scenarios the dust cycle must be modeled.
- A current challenge is poor constraint of the surface mineral composition for the dust source regions of the Earth.
- The VSWIR imaging spectroscopy of EMIT provides a direct and well established method to measure surface mineralogy.
- Initialization of ESMs with EMIT measurements will reduce uncertainty in modeled radiative forcing and allow more accurate investigation of future scenarios.
- EMIT measurements and products will be delivered to the designated NASA DAAC and made available to support a range of scientific research.
- EMIT is scheduled to launch in 2021 and proceed to address its objectives.

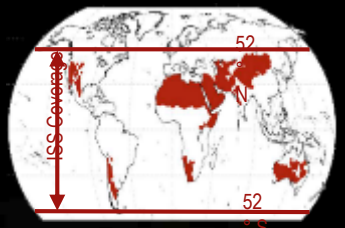
# Thank you




Hematite
Goethtite
Carbonates
Clay Minerals
Illite








Space Imaging Spectroscopy

Particle Emission and Transport

Radiative Forcing

Wet and Dry Depo-sition

Ecosystems and Snow Hydrology Models

Ocean Biology Models

Arid Dust Source Region